Unit C Conclusion

When you began this unit, you were asked to think about the connections between natural phenomena, like the northern lights, and a number of technologies that utilize electromagnetic energy. The key concepts that ran through all of these topics were electric fields and magnetic fields. Motors, generators, and transformers are all technologies based upon the properties of electric and magnetic fields. When these two fields interact, the result is an electromagnetic wave that can be organized into the regions of the electromagnetic spectrum. Long-wavelength radio waves, incredibly tiny X-rays, and the full rainbow of colours within the visible spectrum are all examples of electromagnetic waves.

Throughout the unit you also considered these topics from the point of view of personal health. Whether it's avoiding regions of intense electric field lines under a thundercloud or reducing your exposure to ionizing radiation, the effects of electromagnetic energy require careful consideration. In Unit D you will extend these ideas from the health of an individual to the health of the whole planet.

Career Profile

Biomedical Flight Controller

Tara (Williams) Volpe, a descendant of the Mohawk People, studied Biology at the University of Montreal. Upon graduation, Tara searched for career opportunities in fields that interested her and would utilize her skills. While travelling in Russia, she was fortunate enough to meet NASA employees working in Moscow supporting the *MIR Space Station*. When she inquired about career opportunities in the Manned Space Flight Program, they led her in the right direction.

Tara was hired as a Biomedical Flight Controller at the Johnson Space Centre in Houston, Texas. After several years of training, she worked in Mission Control as a member of the flight control team for the *International Space Station* (ISS). During missions, Tara advised the ISS crew on the operation, maintenance, and repair of the extensive Crew Health-Care System, which includes medical, fitness, and environmental analysis equipment. In addition, she ensured a safe and healthy environment onboard the space station by monitoring the temperature, pressure, and atmospheric gas composition.

Tara is currently working with a team of doctors, engineers, scientists, and astronauts to develop the medical requirements necessary to safely return a human crew to the Moon, and eventually to travel to Mars. With missions lasting up to two-and-a-half years, they need to consider long-term exposure to weightlessness, increased radiation, and, of course, how much food to pack.

Tara loves her job with NASA and advises other Aboriginal students to set their career goals high and reach for the stars.

Unit C Review Questions

1. The following table summarizes the important quantities studied in this chapter. Copy and complete the table in your notebook.

Name	Symbol	Most Common Unit	Equations
gravitational field			
electric field			
magnetic field			
voltage			
current			
resistance			
power			
wavelength			
frequency			
wave speed			
speed of EMR in a vacuum			

2. Define each of the following terms. In each case, include a simple diagram to illustrate the key points in your definition.

a. field **b.** test body **c.** alternating current **d.** transformer

e. electromagnetic radiation **f.** reflection **g.** refraction **h.** diffraction

i. polarization **j.** photon

3. A car's block heater is rated at 1000 W and is plugged in for 12.0 h every night during each of the 31 days in January.

a. Calculate the electrical energy consumed by the block heater in both joules and kilowatt-hours.

b. If the cost of electricity is 9.4¢/kW•h, calculate the cost to operate the car's block heater for all of January.

4. Repeat question 3, only this time assume that the car's owner uses a timer that allows the block heater to turn on for only 3.00 h every day.

5. Refer to your work in questions 3 and 4. Beyond saving money, describe some of the other benefits of using a timer for the car's block heater.

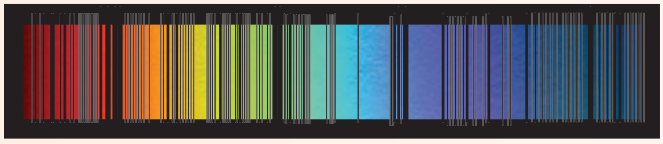
6. A radio station broadcasts to its listeners on a wave with a wavelength of 405.4 m. Calculate the frequency of this broadcast.

7. The human eye is most sensitive to yellow-green light that has a frequency of 5.5×10^{14} Hz.

a. Calculate the wavelength of this light.

b. Suggest a reason why some fire engines and other emergency vehicles are often painted a yellow-green colour.

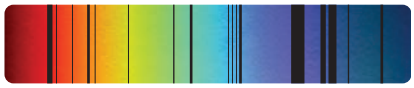
8. The following graphic shows the spectrum of the Sun.



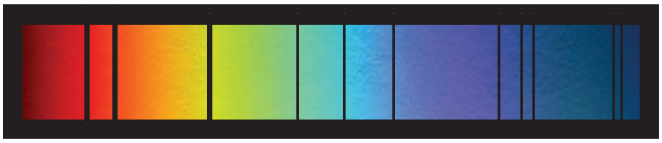
a. Identify this spectrum as a continuous spectrum, an emission spectrum, or an absorption spectrum.

b. Concisely explain why there are dark lines on this spectrum.

9. Obtain the handout "Reference Absorption Spectra" from the Science 30 Textbook CD. Use the information on this handout to help identify the excited gas that produced the following spectrum.



10. The following spectrum was produced by a source that was stationary in relation to the observer.

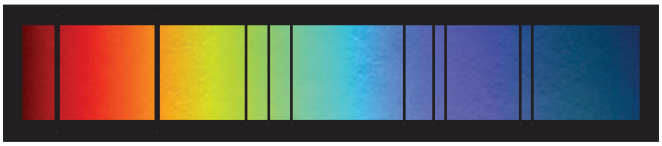


The next spectra were produced by sources that were moving with respect to the observer. In each case, determine whether

- the spectrum is an example of red shift or blue shift
- the source of the spectrum is moving toward the observer or away from the observer

a.

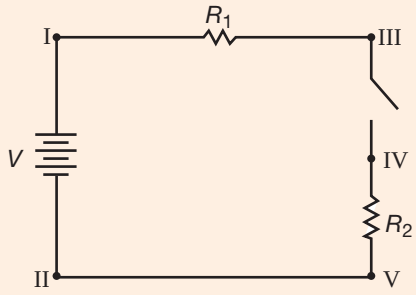
b.



11. Refer to the spectra shown in questions 10.a. and 10.b. Determine which of these two spectra was produced by the faster-moving source. Explain your reasoning.

Use the following information to answer questions 12 and 13.

This circuit shows the connections between two resistors, a switch, and a battery. Note that in addition to labelling the components, each of the contact points in the circuit has been labelled for the purposes of these questions.



12. Describe how you would use other equipment to measure the following values.

a. the voltage across the battery

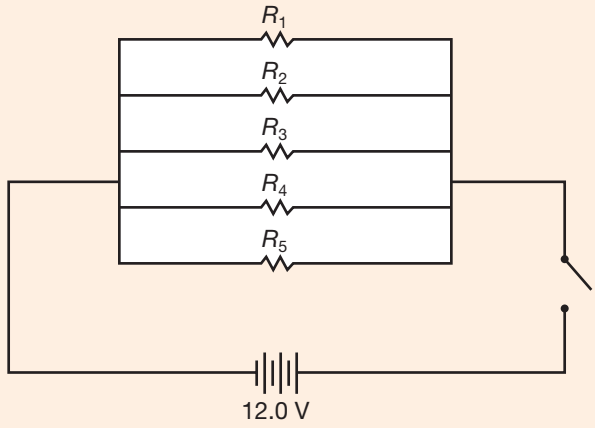
b. the current through resistor R_1

c. the resistance of resistor R_2

13. Calculate the electric current flowing through R_2 given the following values: $V = 6.00$ V, $R_1 = 510\ \Omega$, and $R_2 = 1000\ \Omega$.

Use the following information to answer questions 14 and 15.

The rear-window defroster of a car consists of five heating wires that each have a resistance of 32 Ω. The wires are connected to a switch and to the 12.0-V car battery as shown in the schematic diagram.



14. Calculate the equivalent resistance of the five heating wires.

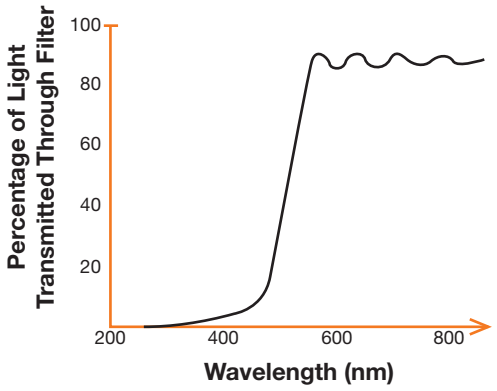
15. Use your answer to question 14 to calculate the current that would flow through the closed switch.

Use the following information to answer questions 16 to 19.

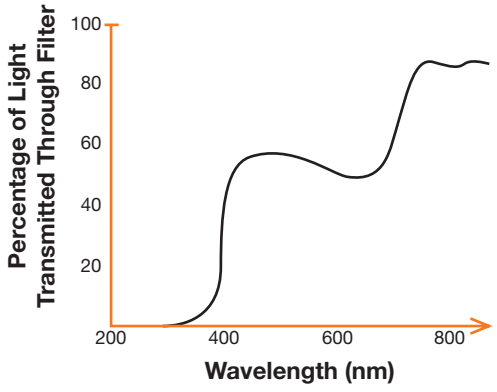
A student went online shopping for a new pair of goggles to be used for snowboarding and downhill skiing. There were many brands to choose from, with a variety of models within each product line. Although the various websites provided photographs, one manufacturer supplied technical data describing the ability of each pair of goggles to transmit various wavelengths of EMR.

Note that the visible spectrum extends from 400 nm to 700 nm.

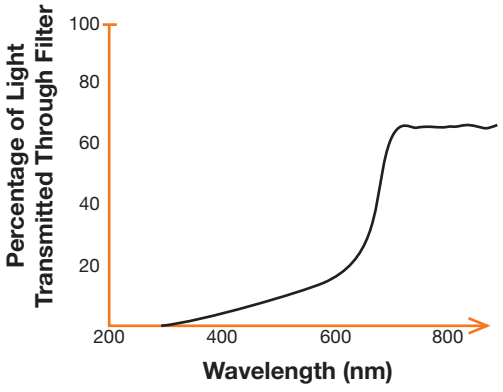
Goggles 1



Goggles 2



Goggles 3



16. Compare the ability of each pair of goggles to transmit ultraviolet radiation.

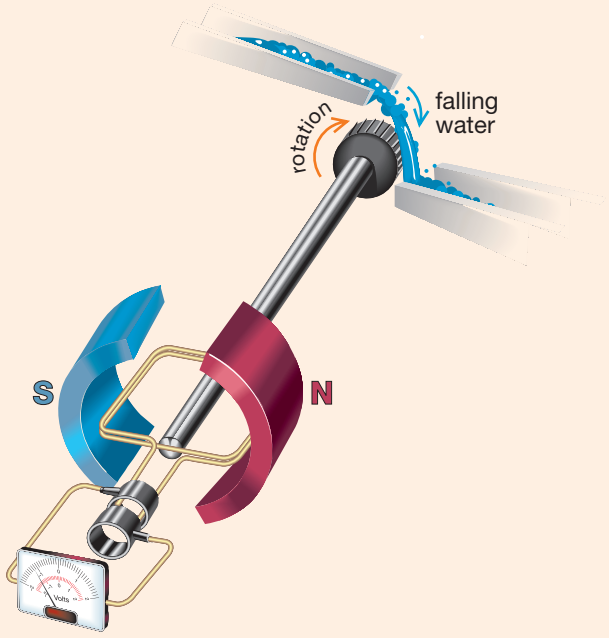
17. Compare the ability of each pair of goggles to transmit infrared radiation.

18. When the full spectrum of solar radiation is analyzed, it is found that more protons with a wavelength of 500 nm arrive at Earth's surface than any other wavelength. Compare the ability of the three pairs of goggles to absorb the energy of the 500-nm photons.

19. Determine which pair of goggles would have the greatest darkening effect on incoming light.

Use the following information to answer questions 20 to 22.

This device transforms an input of mechanical energy into an output of electrical energy.



20. Identify the proper name for this device.

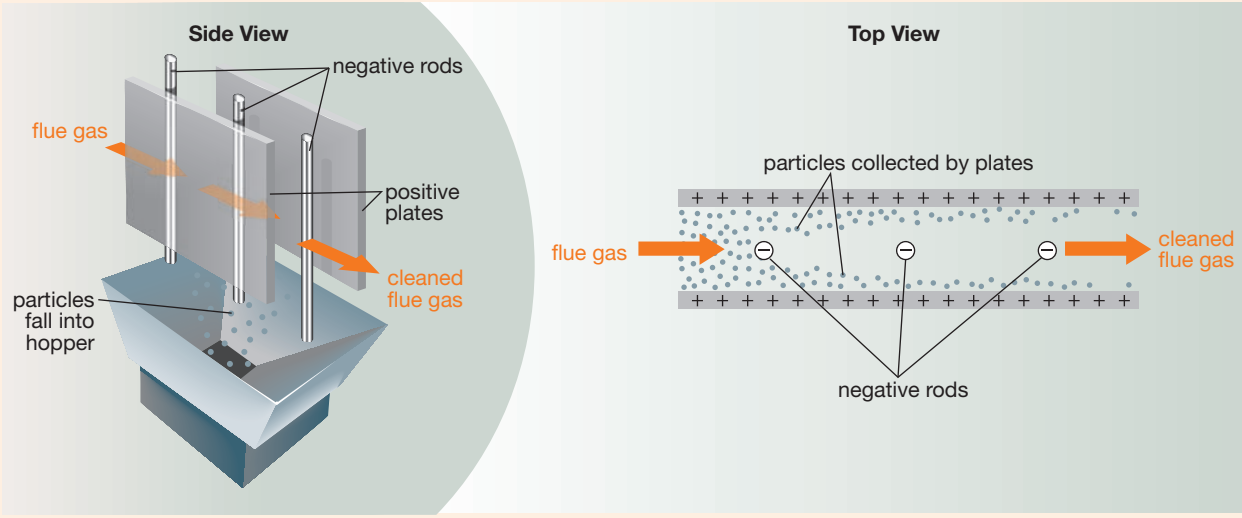
21. Sketch a voltage-versus-time graph to show the output from this device.

22. Repeat question 21 to show how the output would change if the number of rotations per minute was decreased.

Use the following information to answer questions 23 to 27.

Electricity generating stations that burn pulverized coal as a fuel often have particulate matter, such as bits of uncombusted coal, in the exhaust gas that leaves the furnace. This exhaust gas is called flue gas, and the particulate matter in flue gas can be a significant source of air pollution if it is not removed before entering the environment.

The Electrostatic Precipitator



An electrostatic precipitator is designed to remove particulate matter from flue gas. This technology works by positively charging a large number of parallel plates while the metal rods hanging between the plates are negatively charged. As the particles in the flue gas pass the negatively charged rods, the particles pick up negative ions and become negatively charged. These negatively charged particles are then attracted to the positive plates where they are collected. By the time the flue gas has passed through a long column of rods and plates, over 99% of the particulate matter has been removed. Periodically the large positive plates are rapped with automated hammers, causing the particles to drop into the hoppers below the plates.

The following data describes the negative rods and the positive plates for the electrostatic precipitator at one coal-fired power plant:

voltage between the plates and rods = 72.0 kV
electric field between plates and rods = 1.28×10^{5} N/C
typical charge on a very tiny particle in the flue gas = -1.6×10^{-18} C
typical charge on a larger particle in the flue gas = -3.2×10^{-15} C

23. Draw a simple diagram showing the shape of the electric field lines between the negatively charged rods and the positively charged plates.

24. Calculate typical values for the electric force on a very tiny particle and on a larger particle in the flue gas.

25. Concisely explain how the negatively charged rods and positively charged plates are able to exert forces on the moving charged particles in the flue gas even though the particles are not touching the rods or the plates.

26. The electric force values that you calculated in question 24 were quite small. Explain how such small forces are able to produce the desired effects.

27. The electrostatic precipitator is designed to address one of the environmental concerns about burning coal to produce electricity—the release of particulate matter. However, there are other environmental concerns that this technology does not address.

a. List at least two other environmental concerns related to the burning of coal to produce electricity.

b. Describe possible technological fixes for the issues you identified in question 27.a.

c. Many people argue that it is important to think more broadly than simply using one technology to solve the problems created by another technology. Identify some alternative, broad-based strategies that address the environmental concerns related to using coal as a fuel to generate electricity.

Use the following information to answer questions 28 to 30.

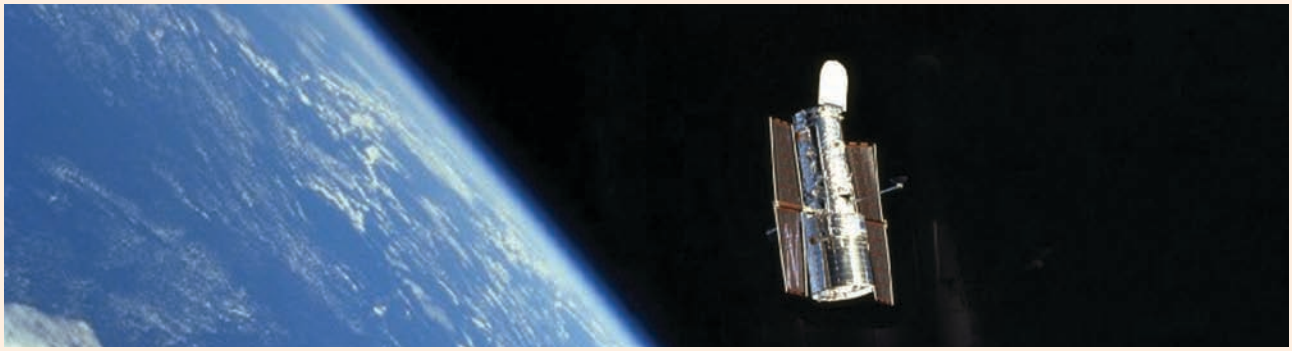
The voltage needed by the negatively charged rods and the positively charged plates in an electrostatic precipitator is supplied by a transformer. The transformer takes an input voltage of 480 V on its primary coil and increases it to 72.0 kV on its secondary coil.

28. Determine whether this is a step-up transformer or a step-down transformer.

29. If there are 80 coils on the primary coil of the transformer, calculate the number of coils on the secondary coil.

30. Would you expect the current in the secondary coil to be larger or smaller than the current in the primary coil? Explain.

Use the following information to answer questions 31 to 38.



The *Hubble Space Telescope* has a mass of 11 600 kg and it orbits Earth at an altitude of 600 km. Earth has a mass of 5.98×10^{24} kg and a radius of 6.37×10^{6} m. The EMR collected by the telescope is analyzed by a spectrometer that has three sensors capable of detecting EMR in the following ranges.

Type of Sensor	Wavelengths of EMR Detected (nm)
cesium iodide detector	115 to 170
cesium telluride detector	165 to 310
charge-coupled device	305 to 1000

Note that the visible spectrum extends from 400 nm to 700 nm.

31. Calculate the strength of the gravitational field of Earth at the location occupied by the *Hubble Space Telescope*.

32. Use your answer to question 31 to calculate the force of gravity that Earth exerts on the *Hubble Space Telescope* at its location in orbit.

33. Compare your answer to question 32 to the force of gravity that Earth exerts on the *Hubble Space Telescope* if it is located on Earth's surface.

34. Use the concept of gravitational field to explain the difference between your answers to questions 32 and 33.

35. Identify the type of sensor on *Hubble's* spectrometer that detects the most EMR with the most energy.

36. Identify the sensor or sensors that are capable of detecting the following types of EMR.

a. infrared radiation **b.** visible light **c.** ultraviolet radiation

37. Explain why these sensors would not be as effective if they were placed on ground-based telescopes on Earth's surface.

38. At the time this textbook was published, NASA was planning a mission to upgrade the *Hubble Space Telescope* in May 2008. The preliminary planning called for a crew of seven to travel on Space Shuttle *Discovery* to deliver nearly 10 tonnes of replacement parts and upgrades. The estimated cost of the mission is US$900 million.

a. In general terms, list some of the benefits of space-based research.

b. In your opinion, do the benefits of space-based research justify the costs? Support your answer by referring to the items you listed in question 38.a.